REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 09-02-2004	**2. REPORT TYPE** FINAL	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE
Commercial Imagery Satellite Threat: How Can U.S. Forces Protect Themselves?

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Denette L. Sleeth

Paper Advisor (if Any): Dr. Elizabeth McIntyre

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Joint Military Operations Department
Naval War College
686 Cushing Road
Newport, RI 02841-1207

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement A: Approved for public release; Distribution is unlimited.

13. SUPPLEMENTARY NOTES A paper submitted to the faculty of the NWC in partial satisfaction of the requirements of the JMO Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.

14. ABSTRACT
Commercially available satellite imagery represents a growing threat to U.S. military operations. To mitigate this threat, the operational commander has a variety of techniques or methods to consider during planning. Some mitigation methods, such as shutter control, diplomacy, or buy-to-deny, require approval and coordination with outside agencies. Other methods, such as jamming, laser blinding, or synchronized operations, require a thoroughly integrated plan to ensure U.S. forces are protected and able to conduct planned movements without enemy interference. Camouflage, concealment, and deception efforts also need to consider the capabilities of commercial imagery platforms and be integrated into operational planning.

15. SUBJECT TERMS
Commercial Imagery, Satellite Imagery, Space Control

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Chairman, JMO Dept
a. REPORT UNCLASSIFIED	**b. ABSTRACT** UNCLASSIFIED	**c. THIS PAGE** UNCLASSIFIED		31	**19b. TELEPHONE NUMBER** *(include area code)* 401-841-3556

Standard Form 298 (Rev. 8-98)

NAVAL WAR COLLEGE
Newport, RI

COMMERCIAL SATELLITE IMAGERY THREAT: HOW CAN U.S. FORCES PROTECT THEMSELVES?

By

Denette L. Sleeth
Major, USAF

A paper submitted to the faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: ________________________

9 February 2004

____
Faculty Advisor
Dr. Elizabeth McIntyre

Abstract

Commercially available satellite imagery represents a growing threat to U.S. military operations. To mitigate this threat, the operational commander has a variety of techniques or methods to consider during planning. Some mitigation methods, such as shutter control, diplomacy, or buy-to-deny, require approval and coordination with outside agencies. Other methods, such as jamming, laser blinding, or synchronized operations, require a thoroughly integrated plan to ensure U.S. forces are protected and able to conduct planned movements without enemy interference. Camouflage, concealment, and deception efforts also need to consider the capabilities of commercial imagery platforms and be integrated into operational planning.

Table of Contents

List of Tables

Table **Page**

Introduction

Over the past 20 years, the world has seen a tremendous increase in space capability. The world of space is no longer bipolar, with the United States and Russia being the only two space-capable nations. Today, every nation is space-capable thanks to the proliferation of commercial satellites and space systems.

What does the expanded availability of commercial space data mean for the operational commander? On one hand, the availability of commercial systems, especially satellite communications (SATCOM) and imagery, represents additional capability U.S. commanders can leverage for operations. On the other hand, it also means that a potential adversary can use those same assets against us. The Pentagon's 1997 Quadrennial Defense Review stated that the United States should develop the ability to prevent hostile use of space by an adversary.[1] Past conflicts have demonstrated the value of commercial SATCOM, particularly mobile systems, to U.S. forces. For example, the United States military contracted three different satellites to provide wideband connectivity for command and control and direct broadcast services during Operation DESERT STORM.[2] Commercial satellite imagery,[3] however, has not historically had the resolution to be of direct military value. As the technology has matured in both data collection and distribution, commercial

---

[1] Department of Defense, "Defense Strategy," Quadrennial Defense Review (Washington DC: May 1997); referenced in Frank G. Klotz, "Space, Commerce, and National Security," A Council of Foreign Relations Paper (New York: Council of Foreign Relations Press, 1998), 16.

[2] Pamela Houghtaling, "Agencies Eye Commercial Birds as Interest in Satellite Grows, 11 November, 1996; referenced in Dennis M. Miller and John E. Stocker III, "Commercialization of Space systems: Policy Implications for the United States (Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2001), 22.

[3] Satellite imagery may be a product of imagery or remote sensing platforms. This paper will not distinguish between them and will refer generically to commercial satellite imagery.

companies have launched higher resolution vehicles and the military usefulness of the available data has increased. Today, anyone with a credit card can purchase high-resolution and multi-spectral images of U.S. bases and areas of operations.[4]

To achieve space control, an enduring enabler of military operations,[5] it is essential not only to protect our own use of space, but also to "prevent adversaries from exploiting U.S., allied, or neutral space services, and negate the ability of adversaries to exploit space capabilities."[6] This includes the use of commercial systems. Our adversaries can use commercial satellite images to locate troop build-up and logistics movement, identify and target high-value assets well behind our lines or in the United States, or see onto bases and operations areas to map out defensive positions and locate possible weaknesses. Commercially available satellite imagery represents a real threat to military operations. The operational commander must ensure all phases of planning integrate mitigation measures to defeat this growing threat.

This paper will look at current and near-term capabilities of commercial imagery satellites and the threat these systems pose to military operations. As possible solutions to this problem, the paper will examine multiple mitigation methods, focusing on methods or techniques that an operational commander can employ today or in the near-term. Note that kinetic kill options against satellites, such as direct ascent or co-orbital anti-satellites (ASAT), are beyond the scope of this paper due to space limitations and the strategic nature of the

---

[4] As Operations Officer of the 527th Space Aggressor Squadron (SAS), the author saw this demonstrated when the squadron made third party (non-military agent using a personal credit card) purchases of commercial imagery of U.S. military facilities and operating locations, including Karshi Kanabad, Uzbekistan, Al Udeid, Kuwait, and Whiteman Air Force Base, MO, from several commercial vendors during Operation Enduring Freedom (OEF).

[5] Joint Chiefs of Staff, Joint Warfare of the Armed Forces of the United States, Joint Pub 1 (Washington DC: 14 November 2000), IV-9.

ASAT issue. The United States does not possess a current or near-term ASAT capability and the deliberate destruction of a non-U.S. satellite is not within an operational commander's authority, requiring high-level consideration of international law, multiple treaties and long-standing U.S. policies.

Commercial Satellite Imagery Platforms and Capabilities.

Commercial imagery satellites have a variety of sensors and several factors affect the type of imagery collected and the practical uses of that data. Depending on what type of data is collected, systems may be electro-optical (EO), infrared (IR), synthetic aperture radar (SAR),[7] or a combination of these. Many systems pair EO and IR sensors to provide day and night capability. Depending on the number of spectral bands collected, EO systems may be panchromatic (pan), imaging in one band of the electromagnetic spectrum and producing black and white images, or multi-spectral, imaging in many discrete bands. Multi-spectral imagery (MSI) systems produce color images in which each color indicates a specific property of the area imaged.[8]

Today, over nine nations and a variety of companies operate commercial imagery satellite systems or sell satellite imagery. Table 1 lists current operational commercial imagery satellites, the system owner, and the advertised resolution. More than 15 additional platforms are scheduled to be launched over the next three years.[9]

---

[6] Joint Chiefs of Staff, Joint Doctrine for Space Operations, Joint Pub 3-14 (Washington DC: 9 August 2002), IV-5.

[7] See Appendix A for additional information on sensor types and collection.

[8] For example, shades of red might indicate ground moisture, with areas of dark red indicating very wet areas and light pink or white indicating dry areas.

[9] Topographic Engineering Center Imagery Office Website, "Status of Selected Current & Future Commercial Civil and Foreign Remote Sensing Satellites." <http://www.tec.army.mil/tio/StatusbyLaunchDate.htm> [30 January 2004].

Table 1
Commercial Imagery Satellites

Satellite	Owner	Type	Resolution[a]
CBERS - 2	China/Brazil	EO/IR	EO - 20 m IR - 80 m
ENVISAT	European Space Agency (ESA)	SAR	10 m
EROS - A1	ImageSat International (Israel)	EO	1.8 m
ERS - 2	ESA	SAR	30 m
IKONOS	Space Imaging (U.S.)	EO MSI	Pan - 1 m MSI - 4 m next generation: .5 meter
IRS - 1C IRS - 1D IRS - P3 IRS - P4	India	EO/IR MSI	Pan - 5.8 m MSI - 24 m
KOMPSAT	Korea	EO	Pan - 6.6m
LANDSAT - 5 LANDSAT - 7	U.S. govt. owned Operated by EOSAT	EO/IR MSI	Pan - 15 m IR - 30 m MSI - 80 m
Orbview - 3	Orbital Sciences Corp./Orbimage (U.S.)	EO, SAR	PAN - 1 meter MSI - 4 meter
PROBA - 1	ESA	EO	3.4 m
QuickBird	Digital Globe (U.S.)	EO MSI	Pan - .61 m MSI - 2.5 m
RADARSAT - 1	Canada	SAR	8 m
RESURS - 01	Russia	EO/IR	EO - 45 m IR - 170 m
SPOT - 2 SPOT - 4 SPOT - 5	CNES/Spot Image (France)	EO/IR MSI	Pan - 10 m, MSI - 20 m Pan - 10 m, MSI - 20 m Pan - 5 m, MSI - 10 m, IR - 20 m
TES	India	EO	Pan - 1m

[a]Resolution type, ground sample distance or pixel, not given.
Source: Multiple sources, see Appendix B.

Threat. Joint Publication 1 defines both surprise and security as guiding principles of war for U.S. forces.[10] Commercially available, high-resolution, satellite imagery threatens the ability of the operational commander to achieve either principle. Commercial images can show an adversary where U.S. forces are staging for an attack. Commercially available imagery also increases the difficulty of maintaining the security of U.S. forces at home and abroad. The availability of these images both threatens U.S. operations and enables enemy operations.

Critical to the process of planning and executing a military operation is intelligence preparation of the battlefield (IPB). Adversary forces can use commercial imagery for their IPB, locating targets in enemy territory and analyzing the battlespace. It is likely that Iraq used SPOT imagery to identify targets and assess damage during its war with Iran. It is also possible that Iraq used SPOT imagery to prepare for the invasion of Kuwait.[11] The U.S. government's effort to track and control the release of high-resolution products from American-based companies acknowledges its concern over this growing threat.[12]

Several aspects of a satellite image determine how useful it will be to a military user. Resolution certainly plays an important role. One-meter and sub one-meter resolution imagery offers substantial military utility, meeting many of the needs of general military intelligence, including detection and identification of many targets. Platforms with lower resolution, such as SPOT or LANDSAT, are also useful. The imagery can be used to search

---

[10] Joint Chiefs of Staff, Joint Warfare of the Armed Forces of the United States, Appendix B.

[11] Laurence Nardon, "The Dilemma of Satellite Imagery Control," *Military Technology*, July 2002, 41.

[12] The Department of Commerce (DoC) licenses commercial vendors. License agreements include the option for the government to implement shutter control during a crisis. Shutter control will be discussed in more detail as a mitigation option. Office of the Press Secretary, "Foreign Access to Remote Sensing Space Capabilities," Fact Sheet (Washington DC: White House, 10 March 1994), 1-2. <http://www.au.af.mil/au/awc/awcgate/space/pdd-23.htm> [3 December 2003].

larger areas, detecting troop concentrations or changes that indicate recent movement or new construction, ruining the element of surprise. Table 2 provides examples of the resolution required to detect, identify and analyze objects of military interest. While current commercial platforms do not offer the resolution required for technical analysis of most objects, they certainly allow for detection and identification of possible military targets. Computer technology allows sensor data to be combined with data from other sensors or systems for hybrid products. High-resolution imagery can be combined with elevation data for computer-simulated rehearsals or training events in preparation for a military operation.

Table 2
Ground Resolution (Meters) Requirements for Object Identification

Target[a]	Detection[b]	General ID[c]	Precise ID[d]	Description[e]	Technical Analysis[f]
Bridges	6	4.5	1.5	1	0.3
Communications					
Radar	3	1	0.3	0.15	0.015
Radio	3	1.5	0.3	0.15	0.015
Troop Units					
Bivouac or on road	6	2	1.2	0.3	0.15
Airfield Facilities	6	4.5	3	0.3	0.15
Rockets/Artillery	1	0.6	0.15	0.05	0.045
Aircraft	4.5	1.5	1	0.15	0.045
Surface Ships	7.5	4.5	0.6	0.3	0.045
Vehicles	1.5	0.6	0.3	0.06	0.045
Ports and Harbors	30	15	6	3	0.03
Roads	6-9	6	1.8	0.6	0.4

[a]Chart indicates minimum resolution (ground sample distance) in meters.
[b]Detection: location of a class of units, object, or activity of a military unit
[c]General Identification: determination of general target type
[d]Precise Identification: discrimination within a target group
[e]Description: size/dimension, configuration/layout, component construction, equipment count, etc
[f]Technical Analysis: detailed analysis of specific equipment
Source: James G. Lee, "Counterspace Operations for Information Dominance," in Beyond the Paths of Heaven: The Emergence of Space Power Thought, edited by Bruce M. DeBlois (Maxwell Air Force Base, AL: Air University Press, 1999), 266.

The color images produced by MSI platforms are a growing industry. Although designed for specific civil applications, the data can also be used for a variety of military purposes, representing a growing threat to military operations. Planners can use MSI data to determine ground hardness for possible vehicle movement, identify areas of thick vegetation where ground force movement will be difficult, and identify areas suitable for amphibious or airborne assault. MSI data can effectively defeat many camouflage efforts, since it can differentiate between actual foliage and camouflage material based on moisture content.[13] Table 3 shows some of the military applications of MSI data with the associated civil use.

Table 3
Civil and Military Applications of MSI

Civil Application	Military Application
Soil Features	Terrain Delineation, Attack Planning, Trafficability
Surface Temperature	ASW Support, Trafficability, Airfield Analysis
Vegetation Analysis	Terrain Delineation, Camouflage Detection
Clouds	Weather, Attack Planning
Snow Analysis	Area Delineation, Attack Planning
Surface Elevation	Mapping, TERCOM
Ice Analysis	Navigation, ASW Support
Water Analysis	Amphibious Assault Planning
Cultural Features	Targeting, Battle Damage Assessment

Source: James G. Lee, "Counterspace Operations for Information Dominance," in Beyond the Paths of Heaven: The Emergence of Space Power Thought, edited by Bruce M. DeBlois (Maxwell Air Force Base, AL: Air University Press, 1999), 270.

Timeliness, or how quickly the customer receives an imagery product, is often critical for a military user. Imagery that takes days or weeks to receive may be of limited tactical value to a military commander, but is useful for operational planning. Several factors determine how responsive commercial satellite imagery systems can be. Satellite orbitology

[13] Larry K. Grundhauser, "Sentinels Rising: Commercial High-Resolution Satellite Imagery and Its Implications for U.S. National Security," *Airpower Journal*, Winter 1998, 66.

plays a large role. Most imagery satellites maximize resolution by using low earth orbits. This means they are always moving and cannot constantly monitor a target area. How often a platform can revisit a particular target depends on the field of view of the sensor and the location of the target on the ground. A wide field of view means the satellite can see targets farther away from its ground trace. Because most imagery satellites are highly inclined, targets near the equator have lower revisit rates. Many current commercial imagery satellites have revisit rates between three and eight days. A system with multiple satellites may revisit a target area daily.

Where a user request falls in the tasking priority will determine how quickly an image is attempted. For a high interest area, where multiple customers are requesting images of specific areas, it may take weeks or longer for a request to be filled. For some applications, bad weather or cloud cover may delay a request. Once the satellite does collect the image, how quickly is it processed and disseminated to the user? Processing alone may take several days. U.S. licensed companies cannot release images within 24-hours of collection.[14]

The capability to download satellite data directly minimizes the delays in tasking, processing and delivery. Several commercial venders contract ground stations to foreign countries or companies. In the case of Israeli's ImageSat, the company sells the rights to both control satellite tasking over a specific region and receive real-time data.[15] Space Imaging, an American company, sells ground station options to individual customers and allows regional

---

[14] Digital Globe Website, "Product Release Policy." <http://www.digitalglobe.com/> [25 January 2004].

[15] "Taiwan's Use of Satellites for Surveillance Against China Described," FBIS, translated from Guangzhou Guangzhou Ribao (Internet Version), 16 February 2003. <http://www.fbis.cia.sgov.gov/doc_lib/2003/002/10/CPP20030219000068N.html> [9 January 2004].

affiliates to purchase imaging time on the satellite and own the rights to the imagery collected within the purchased zone.[16]

The U.S. military has gone a step farther and developed a system of small, deployable ground stations to collect and process commercial imagery in theater. Called Eagle Vision vans, these ground stations can receive direct downlinks of imagery data from SPOT, LANDSAT, RADARSAT, IRS, and Orbview.[17] These systems mean commercial satellite imagery is available near real-time and becomes tactically relevant. Potential adversaries can also have direct downlink if they are willing to pay for it.

Mitigation Methods

There are many methods an operational commander should consider employing to mitigate the threat of commercially available satellite imagery. Each method has advantages and disadvantages. In the world of commercial satellites, the owner or owners of the system may drive which mitigation technique a commander is able to employ or recommend. Because these are commercial platforms, profit is usually the owner's driving concern.

The first three methods are options the United States has employed. While an operational commander should consider these options, all require implementation at a higher level. Time may also play a role in determining if one of these methods is feasible. The last five options can be implemented at the operational level.

---

[16] Space Imaging currently has regional affiliates in Japan, Korea, UAE and Turkey. Space Imaging, Inc, "Addressing a Global Need for Virtual Information." <http://www.spaceimaging.com/corporate/overview4.htm> [25 January 2004].
[17] James A. Hartmetz, "Eagle Vision--Exploiting Commercial Satellite Imagery," *DISAM Journal of International Security Management*, Summer 2001, 23.

Shutter Control.[18] Shutter control was designed to prevent an adversary from using U.S. commercial systems during a conflict.[19] It is implemented through licensing requirements. The Department of Commerce (DoC) licenses U.S. companies. The following conditions are imposed by the license: the owner must maintain a record of satellite tasking for the previous year, provide government access to the tasking record, use only government-approved data encryption schemes and downlink formats, notify the government prior to entering into any foreign contracts, and accept data collection limits based on national security.[20]

While shutter control seems to offer the operational commander a clean, relatively easy way to prevent an adversary from obtaining commercial imagery, there are several limitations. The most obvious one is that shutter control only applies to U.S.-owned systems. As shown in Table 1, many foreign companies also have commercial systems. There are also both legal and economic concerns. Members of the Radio-Television News Directors Association have questioned the legality of shutter control. They say that the government cannot interfere with any publication, including satellite imagery, without demonstrating clear

---

[18] In 1984, Congress tried to promote the commercialization of land remote sensing satellites by privatizing the LANDSAT program. While the initial effort failed, subsequent efforts in 1992 and a 1994 Clinton Administration policy led several U.S. companies to develop commercial remote sensing satellite systems. Current U.S. policy seeks to both promote U.S. leadership in commercial ventures and provide government control through assured access and shutter control. Assured access implements controls and safeguards to protect the system for government use. Marcia S. Smith, "U.S. Space Programs: Civilian, Military, and Commercial," CRS Issue Brief for Congress (Washington DC: Congressional Research Service, Updated October 6, 2003), 4.

[19] Smith, 4-5.

[20] Office of the Press Secretary, "Foreign Access to Remote Sensing Space Capabilities," 1-2.

and present danger to a court.[21] Legal action might limit when shutter control can be implemented.

During Operation ENDURING FREEDOM (OEF), the U.S. government opted to buy exclusive rights to all IKONOS imagery of Afghanistan at a cost of almost $2M a month.[22] Not only is this option very expensive for the government, it may be counterproductive to the stated policy goal of enhancing U.S. industrial competitiveness in satellite remote sensing. Prospective customers will seek alternate sources of data if they fear the United States will routinely restrict access.

Since DoC implements shutter control, a combatant commander would have to request action through the Secretary of Defense during planning. Since U.S. policy is to use commercial imagery to augment national capabilities, the request must be deconflicted with a number of intelligence agencies, slowing the process. A request to implement shutter control would need to demonstrate that vital interests are at stake and indicate the level of control required. For example, to protect staging operations of a special operations force, a simple delay in the transmission of any images of the staging area may suffice. Total denial may not be necessary. Because shutter control needs to be coordinated through several agencies and departments, a commander may not have time to implement this option during a quick response to an unexpected crisis.

A form of shutter control may be embedded in technology transfer and future cost-sharing agreements with friendly and allied governments. This would require government-to-government agreements or similar arrangements concerning the denial of products and data to

[21] Grundhauser, 74; and Michael J. Sowa, "Shutter Control Feasibility and Employment Considerations" (Unpublished Research Paper, USAF Weapons School, Nellis Air Force Base, NV: 2000), 4.

[22] James R. Asker, "Washington Outlook," *Aviation Week & Space Technology*, October 22, 2001, 25.

specific customers during a conflict.[23] Again, there is a balance between protecting U.S. interests and promoting profitable enterprises. Another option would be for the United States to sponsor a legally binding treaty defining the rights and obligations of remote-sensing countries with respect to data distribution. This would require signing states to be capable of exercising shutter control when necessary.[24]

Diplomacy. One option to deny an adversary access to foreign systems is through diplomacy. Government to government interaction may be enough to convince a corporation to suspend access during a conflict. This option was used during Operation DESERT STORM. The Iraqi government bought French SPOT imagery before the war but international condemnation of Iraq's invasion of Kuwait prompted France's SPOT Image to deny Iraq further imagery. The United Nations mandated an embargo on satellite imagery sales to Iraq.[25] SPOT Image also refused to provide imagery of the region to television or other media outlets, but reserved the right to do so if another source provided imagery to the media.[26]

A diplomatic option is dependent on the United States having strong international support and the country or countries of the satellite owner agreeing with U.S. military actions. Coalition partners will also have troops and facilities at risk, adding pressure to native companies. As commercial satellite systems proliferate, it will be more difficult to gain the consensus of the owner of every platform. This will be especially difficult if an international

---

[23] Office of the Press Secretary, "Foreign Access to Remote Sensing Space Capabilities," 2-3.

[24] Grundhauser, 78.

[25] Essays on Air and Space Power, Vol. II (Maxwell Air Force Base, AL: Air University Press, 1997), 117; referenced in Robert A. Fabian, "Force Protection in an Era of Commercially Available Satellite Imagery: Space Blockade as a Possible Solution" (Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2002), 7.

[26] James R. Shumate, "Information Weaponization of Space" (Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2001), 8.

consortium owns the platforms. Another drawback to diplomacy is timeliness. Diplomatic channels are often slow and in a crisis may not work fast enough to prevent the enemy from having access to commercial imagery.

Buy-to-Deny. Another option to control non-U.S. systems is for the U.S. government to buy all of the imagery over a theater. Given the increasing number of commercial imagery sources, this option quickly becomes cost prohibitive. There are also contractual issues. As mentioned earlier, companies are selling ground stations and satellite control options to other agencies. These commercial companies are in business to make a profit. They may not be willing to break contracts, especially with users who are not a direct party to the conflict.

One of the problems with shutter control, diplomatic and buy-to-deny proposals is defining the area of restricted access. For example, during OEF, the United States purchased high-resolution imagery over Afghanistan, but did nothing to protect operating locations and bases in neighboring areas.[27] Commercial imagery can pose a threat to assets outside the immediate area of operations, such as staging areas, lines of communications, and intermediate bases. The operational commander must establish a balance in deciding the actual area to protect. The area to protect may also change as the operation progresses, further complicating the process.

To this point, the commander's options have required long lead times and the involvement of higher echelons and outside agencies. While a combatant commander might include them in an operation or concept plan, there are also options more directly under the combatant commander's control.

[27] 527 SAS obtained IKONOS imagery of U.S. operating locations, such as Karshi Kanabad and Al Udeid, during the restriction over Afghanistan.

Jamming. Jamming is a non-destructive option that can be directly controlled by the operational commander. A space system consists of three segments, space, control, and user, and the links between them. The space segment is the actual satellite. The control segment consists of ground facilities that monitor the health of the satellite and provide command and control for maintenance activities and sensor tasking. The user or terminal segment receives the satellite data and in some systems, may be able to task the sensor as well.

A commander has the option of jamming the uplink or the downlink. Jamming the uplink can prevent the satellite owner or a user from tasking the satellite to collect imagery. This requires the planner to know when and where payload tasking is uploaded to the satellite. Mission uploads might be done from a central command and control station on a regular schedule or by users at distributed ground stations. A possible complication to this option is that the jamming platform requires line-of-sight to the satellite while the satellite is also within view of the ground station. This may not be possible or practical if the station is within the territory of a neutral or non-cooperative nation. The ground station might not even be within the combatant commander's theater. Jamming the uplink or downlink of a ground station in another country would have to be done covertly and would require a higher level of approval, to include both legal and political ramifications.

If an adversary receives satellite data directly to a user terminal in theater, downlink jamming is an option. In this case, the ground station is more likely to be within the commander's area of operations and easier to target. The Army would most likely do in-theater jamming. As part of current electronic warfare missions, the Army already has vehicle-mounted communications jammers.[28] Satellite links just represent new frequencies to

[28] "Electronic Warfare Factbook," Land Information Warfare Activity (30 August 2002). <http://www.lima.army.smil.mil/techdata/handbook/ew_factbook_3.pdf> [28 January 2004].

jam. If the jammer is required to be outside of the theater, another agency or department might operate the jammer. If jamming ground stations near the shore, for example, the commander might use a naval platform.

As a whole, the system presents several links susceptible to jamming. Joint Task Force-level planning will be required to identify the best link or node to jam. The location and parameters of the target signal will then determine the best platform to employ against it.

Laser blinding. Laser blinding or dazzling is a form of jamming an imaging sensor. A low powered laser in the correct wavelength can temporarily blind an imaging satellite by overloading the sensor as it passes overhead.[29] Like jamming, it can be a non-destructive option. It is a useful method for area denial, since the laser must have line-of-sight to the satellite as it passes over the area the commander does not want imaged.

Unfortunately, laser jamming is not the perfect solution. The Army test-fired a laser at a satellite in 1997 and continues to work on a laser blinding system. Both technical and political challenges have slowed development of an operational system for use in-theater. Developing a mobile or transportable tracking system accurate enough to hit a satellite sensor with a laser is one challenge. On the political side, some opponents of ground-based laser systems see all lasers as ASAT weapons and classify any laser testing and development as provocative.[30]

Synchronized operations. Historically, one method used to avoid detection or observation by foreign overhead systems was to limit sensitive activities while those assets were in view. Predicting periods of vulnerability for commercial assets is relatively easy.

[29] Shumate, 10.

The United States closely tracks all satellite orbits and commercial vendors generally advertise factors like sensor sensitivity and field-of-view to attract customers. Computer programs use this information to determine when a satellite can image a specific location. Once determined, vulnerability periods are distributed to units or activities that are sensitive so that they can limit their activities during these periods. This approach is fine for dealing with a relatively small number of foreign systems but may soon be too restrictive as the number of observation systems grows.

Limiting activities is not an effective mitigation method for activities such as the movement of large numbers of troops, operations at assembly areas, construction projects and most routine airfield operations.[31] Despite these drawbacks, if the United States is operating as part of a coalition or has broad international support, the number of commercial companies willing to provide imagery to the adversary will diminish, possibly making this a workable option.

Camouflage, Concealment and Deception. Camouflage, concealment and deception (CCD) are other means to defeat the proliferation of commercial imagery. CCD can be as simple as covering equipment with tarps or dispersing units under trees. It can also be very sophisticated, involving feints with forces or elaborate mock-ups of equipment. The key to CCD is to plan for its use throughout an operation. The spread of new technologies, such as hyper-spectral imagery (HSI), will make camouflage and concealment in the future more difficult. Every material has a distinct spectral return based on its composition. HSI systems can use this information to distinguish between leaves and camouflage netting or aluminum

---

[30] Daniel G. Dupont, "Army Continues to Refine Laser's Ability to Track, Defeat Satellites," *Inside the Army*, November 30, 1998. <http://www.elastic.org/~fche/mirrors/www.jya.com/miracl-asat.htm> [26 February 2004].

and steel. Currently, space-based HSI systems are still in the research and development phase.

Physical Destruction. While the satellite may be out of reach, physical destruction of the ground station that receives the imagery data from the satellite may be a valid option. This will be particularly true if the downlink station is located in the area of hostile operations. As with any target, collateral damage is a concern and may include neutral nation property and personnel in this case. The proliferation of smaller vans and mobile downlink terminals will make them harder to find and destroy.

An Integrated Plan

The solution is a well thought-out plan, with consideration of the commercial satellite threat integrated into planning from the outset. Commercial satellite imagery represents a growing source of intelligence for any current or future adversary. It must be considered a valid threat to our forces and operations and incorporated into deliberate and crisis action planning just as we would incorporate the threat of hostile military intelligence satellites.

What does this really mean? To start with, it adds another layer or facet of intelligence needed by the combatant commander and his planners. Planners need to know where potential adversaries are obtaining commercial imagery and how quickly it is available. Is the imagery being controlled and distributed from the parent company or received directly through a remote ground station? Does the adversary have direct control over the imaging sensor in the area of operations? What is the adversary's relationship with the company and the company's home nation or nations? Does the adversary use multiple sources? The answers to these questions will affect the commander's available options to mitigate this

[31] Anthony J. Russo, "The Operational Denial of Commercial Space Imagery" (Unpublished Research Paper,

threat. The planning process needs to consider all of the available options and integrate the best alternatives into each phase of the operation.

If the adversary is obtaining imagery from U.S.-owned companies, the commander should consider requesting shutter control. Imagery obtained from companies in nations supporting our efforts might be denied through diplomatic means. To minimize the economic and third party impacts of these methods, the combatant commander must determine specific areas that need to be denied and define reasonable timeframes. Companies will be more willing to voluntarily cooperate if limits are implemented. Total denial over a theater for the duration of an operation will not be a valid option but denial over a defined area for short, critical, periods may be acceptable. It might be that total denial is not even required. Companies can be asked to delay dissemination or degrade the quality of the imagery released to meet the commander's needs.

Since there are multiple systems available to an adversary, it is not likely that shutter control or diplomacy can eliminate the entire threat. Other methods will be required to deny imagery from commercial vendors who support the adversary or who are unwilling or unable to cooperate voluntarily. This is where jamming the data link or laser blinding might be the best options.

In the future, the sheer number of imagery platforms will probably not allow commanders to prevent overhead imaging of many activities, but careful planning can add a level of covertness to activities. Thorough integration of CCD into planned operations is critical since CCD operations require both time and effort to effectively employ.

Counterarguments. How much of a threat does commercial satellite imagery really pose? We have already seen some examples of its use. Commercial satellite images of

---

U.S. Army Command and General Staff College, Ft Leavenworth, KS: 1996), 46-47.

potential staging areas for the attack on Iraq in the Horn of Africa were broadcast around the world and posted on the Internet.[32] Our own use of commercial imagery to support recent operations also proves its military worth. Commercial imagery was used to determine force protection requirements for a new unmanned aerial vehicle site in the Iraqi theater and the 12th Air Defense Artillery used commercial MSI to determine where to deploy heavy equipment in An Nasiriyah.[33] The Air Force has developed portable ground stations to allow commanders to receive real-time commercial imagery in theater. The Taiwanese military has purchased commercial imagery for intelligence purposes since the 1980s. Taiwan currently uses both IKONOS and EROS-A1 imagery for surveillance and reconnaissance of China and formed a special unit to plan collection requirements and interpret images. They are also researching the interpretation requirements of HSI for use in areas such as target detection.[34] The proliferation and military utility of commercial satellite imagery makes it a definite threat to military operations.

As with most information, there is a gain-loss argument. Letting an adversary see our strength, readiness and preparation for conflict may serve as a deterrent and facilitate a diplomatic solution to an emerging conflict. Deception activities can also use the proliferation of commercial imagery to our favor. A commander can purposely stage actions in view of commercial platforms as part of a deception campaign. Denial actions, such as jamming or laser dazzling, can also be used as a deception technique. Denying imagery of an area will draw attention and resources to that area, even if the only military activity there is

---

[32] Richard B. Myers, "A Word from the Chairman: Shift to Global Perspective," *Air and Space Power Journal*, Fall 2003. <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj03/fal03/myers.html> [9 January 2004].
[33] Jefferson Morris, "Commercial Satellite Imagery 'Key' in Iraq, NIMA Official Says," *Aerospace Daily*, May 16, 2003. <www.dia.smil.mil/admin/EARLYBIRD/030519/s20030519186090.html> [9 January 2004].

[34] "Taiwan's Use of Satellites for Surveillance Against China Described."

the jamming. This is another reason operational planning is critical. That is where the gain-loss question must be considered and settled.

Advances and proliferation of MSI systems will make CCD harder and more expensive to successfully implement in the future. Advanced systems coupled with software will be able to distinguish between types of paint, identify surface materials, and see targets under camouflage netting. CCD techniques will have to advance, as well, to remain a valid mitigation technique.

The fact that this threat involves commercial companies, not government or military agencies, adds a layer of complexity to the mitigation problem. Suddenly the commander is considering actions that may be considered hostile by a country or countries not directly involved in the conflict. The development and launch of space systems is very expensive and many satellite systems are owned or financed by multiple companies, representing multiple countries or international consortia. There is also a wide range of uses for commercial imagery. Actions taken to deny an adversary may affect legitimate, non-hostile, third party users. During OEF, the government's initial control over IKONOS images of Afghanistan prevented non-governmental and international aid agencies from obtaining needed images of the area for humanitarian mission planning.

These concerns only increase the importance of the planning effort, especially with regard to third party users. During planning, the commander should consider collateral effects and try to identify solutions prior to conflict. For example, the military or another organization, such as the National Geospatial-Intelligence Agency, might be able to provide older, archived or less accurate images to meet the needs of other agencies.

Conclusion

Space control operations, as defined in Joint Publication 3-14, "provide freedom of action in space for friendly forces while, when directed, denying it to an adversary, and include the broad aspect of protection of U.S. and U.S. allied space systems and negation of adversary space systems."[35] The growing world of commercial satellites presents a new challenge to the commander trying to achieve space control for his theater. Every potential adversary now has access to high-resolution satellite imagery, posing a significant threat to U.S. forces. While the operational commander has many mitigation techniques to prevent an adversary from using commercial imagery against his forces, deliberate planning will be critical to obtaining approvals, deconflicting operations and ensuring minimal impact of this threat.

[35] Joint Chiefs of Staff, Joint Doctrine for Space Operations, IV-5.

Appendix A
Sensor Term Definitions

The basic types of imagery sensors are electro-optical[*] (EO), infrared (IR) and synthetic aperture radar (SAR). EO sensors collect data based on reflected light. Since EO depends on light for illumination, it is typically used to image during daylight. Cloud cover will obscure EO images. EO images are usually easier to interpret than IR or SAR images since they resemble photographs. IR sensors collect electromagnetic radiations emitted or reflected from a given target surface in the infrared range of the spectrum, producing images that show temperature gradients. IR is often employed during darkness but can be used in daylight. IR sensors can be used to monitor heat sources, such as industrial exhaust or rocket motors. Cloud cover also degrades IR imagery. SAR images are usually more difficult to interpret but provide insight into materials and structure of a given target. SAR is the only true day/night, all-weather capability. A single satellite may have a combination of sensors on-board.

Spatial resolution is a critical factor in determining the possible uses of imagery. For some EO platforms, resolution may be defined as ground sample distance, which is a measure of the minimum distance required between two objects for them to be discernable as separate on the image. For other EO systems, resolution is defined as pixel resolution. For a sensor with a pixel resolution of 10 meters, each pixel in an image represents a square 10 meters by 10 meters. Generally, an object must cover at least two and a half pixels to be distinguished, so for a 10-meter pixel resolution, two objects must be at least 25 m apart to appear as distinct. The actual resolution of an image will also depend on where the satellite is in its orbit, since many satellites vary in altitude through each orbit, and the look angle of the sensor. A customer will receive the best resolution when the satellite is at the lowest altitude in its orbit with the sensor looking directly below the satellite.

The last factor is the number of electromagnetic frequency bands collected. Panchromatic images are single band, providing the equivalent of black and white photos. Multi-spectral imagery (MSI) covers multiple bands (4 - 100) and hyper-spectral imagery (HSI) collects data in hundreds of discrete bands. MSI and HSI are displayed as false-color images with a key explaining what the colors indicate. MSI and HSI have many applications, such as determining moisture content, type and density of foliage, or ground composition and countering camouflage, concealment, and deception (CCD) techniques.

MSI and HSI images can provide a great deal of information but there is a trade-off. Satellite systems are limited by how much data they can collect, store, if required, and downlink to the ground. There is also a time factor. For a given data rate, it takes longer to transmit a larger amount of data. Since panchromatic sensors collect fewer bands of information, the images are higher resolution than MSI or HSI. Panchromatic sensors also usually have a larger field of view and can image a larger area during each pass.

[*] The term electro-optical also describes the method of data collection, digital as opposed to on film.

Appendix B
Data Sources for Table 1
Commercial Imagery Satellites

Baker, David, ed. Jane's Space Directory, Fifteenth Edition 1999-2000. Alexandria, VA: Jane's Information Group, 1999.

Digital Globe Website. <http://www.digitalglobe.com/> [25 January 2004].

EOEdu, Observing Our Planet. "Satellites and Sensors." Belgian Earth Observation Website. <http://telsat.belspo.be/beo/en/guide/index.htm> [12 January 2004].

Satellite Imaging Corporation Website. <http://www.satimagingcorp.com/> [12 January 2004].

Space Imaging, Inc. Website. <http://www.spaceimaging.com/> [25 January 2004].

Tag's Broadcasting Services Website. "The Satellite Encyclopedia." <http://www.tbs-satellite.com/tse/online/mis_teledetection_res.html> [12 January 2004].

Topographic Engineering Center Imagery Office Website. "Status of Selected Current & Future Commercial Remote Sensing Satellites by Launch." <http://www.tec.army.mil/tio/StatusbyLaunchDate.htm> [30 January 2004].

Bibliography

Asker, James R. "Washington Outlook." *Aviation Week & Space Technology*, October 22, 2001, 25.

Baker, David, ed. Jane's Space Directory, Fifteenth Edition 1999-2000. Alexandria, VA: Jane's Information Group, 1999.

Commission on the Roles and Capabilities of the United States Intelligence Community. "Space Reconnaissance and the Management of Technical Collection." Preparing for the 21st Century - An Appraisal of U.S. Intelligence. August 2000. <http://www.access.gpo.gov/intelligence/int/int015.html> [3 December 2003].

Digital Globe Website. <http://www.digitalglobe.com/> [25 January 2004].

Dupont, Daniel G. "Army Continues to Refine Laser's Ability to Track, Defeat Satellites." *Inside the Army*, November 30, 1998. <http://www.elastic.org/~fche/mirrors/www.jya.com/miracl-asat.htm> [26 February 2004].

"Electronic Warfare Factbook." Land Information Warfare Activity, 30 August 2002. <http://www.liwa.army.smil.mil/techdata/handbook/ew_factbook_3.pdf> [28 January 2004].

EOEdu Observing our Planet. "Satellites and Sensors." Belgian Earth Observation Website. <http://telsat.belspo.be/beo/en/guide/index.htm> [12 January 2004].

Essays on Air and Space Power, Vol. II. Maxwell Air Force Base, AL: Air University Press, 1997. Referenced in Robert A. Fabian, "Force Protection in an Era of Commercially Available Satellite Imagery: Space Blockade as a Possible Solution," 7. Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2002.

Fabian, Robert A. "Force Protection in an Era of Commercially Available Satellite Imagery: Space Blockade as a Possible Solution." Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2002.

Florini, Ann M. "The Opening Skies: Third-Party Imaging Satellites and U.S. Security." *International Security*, Autumn 1988, 91-123.

Florini, Ann M. and Yahya A. Dehqanzada. "No More Secrets: Policy Implications of Commercial Remote Sensing Satellites." Global Policy Program: Project on Transparency, Working Paper Number 1, July 1999. <http://www.ceip.org/programs/governance/RemoteSensingConf/NoMoreSecrets2.htm> [5 December 2003].

Gildea, Kerry. "Lawmakers Put Pressure on DoD to Devise Commercial Imagery Strategy." *C4I News*, June 6, 2002. Search Terms "Commercial Imagery" on Lexis-Nexis. Dayton, OH: Lexis-Nexis. [1 December 2003].

Grundhauser, Larry K. "Sentinels Rising: Commercial High-Resolution Satellite Imagery and Its Implications for U.S. National Security." *Airpower Journal*, Winter 1998, 61-80.

Hartmetz, James A. "Eagle Vision--Exploiting Commercial Satellite Imagery." *DISAM Journal of International Security Management*, Summer 2001, 22-25.

Houghtaling, Pamela. "Agencies Eye Commercial Birds as Interest in Satellite Grows." November 11, 1996. <http://208.201.97.5/pubs/fcw/111/feat.htm> Referenced in Dennis M. Miller and John E. Stocker III, "Commercialization of Space Systems: Policy Implications for the United States," 22. Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2001.

Klotz, Frank G. "Space, Commerce, and National Security." A Council of Foreign Relations Paper. New York: Council of Foreign Relations Press, 1998.

Lee, James G. "Counterspace Operations for Information Dominance." In Beyond the Paths of Heaven: The Emergence of Space Power Thought, edited by Bruce M. DeBlois, 249-301. Maxwell Air Force Base, AL: Air University Press, 1999.

Miller, Dennis M. and John E. Stocker III. "Commercialization of Space Systems: Policy Implications for the United States." Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2001.

Mehuron, Tamar A. "Space Almanac." *Air Force Magazine: Journal of the Air Force Association*, August 2003, 21-60.

Moorman, Thomas S. "The Explosion of Commercial Space and the Implications for National Security." *Aerospace Power Journal*, Spring 1999. <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj99/spr99/moorman.html> [9 January 2004].

Morris, Jefferson. "Commercial Satellite Imagery 'Key' in Iraq, NIMA Official Says." *Aerospace Daily*, May 16, 2003. <www.dia.smil.mil/admin/EARLYBIRD/030519/s20030519186090.html> [9 January 2004].

Myers, Richard B. "A Word from the Chairman: Shift to Global Perspective." *Air and Space Power Journal*, Fall 2003. <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj03/fal03/myers.html> [9 January 2004].

Nardon, Laurence. "The Dilemma of Satellite Imagery Control." *Military Technology*, July 2002, 37-46.

National Defense Panel. Transforming Defense: National Security in the 21st Century. Arlington, VA: December 1997.

O'Connell, Kevin M., and others. U.S. Commercial Remote Sensing Satellite Industry: An Analysis of Risks. Study prepared for the U.S. Department of Commerce. Santa Monica, CA: Rand, 2001.

Office of the Press Secretary. "Foreign Access to Remote Sensing Space Capabilities." Fact Sheet. Washington DC: White House, 10 March 1994. <http://www.au.af.mil/au/awc/awcgate/space/pdd-23.htm> [3 December 2003].

____. "U.S. Commercial Remote Sensing Policy." Fact Sheet. Washington DC: White House, 25 April 2003. <http://www.au.af.mil/au/awc/awcgate/space/2003remotesensing-ostp.htm> [3 December 2003].

____. "U.S. Commercial Remote Sensing Space Policy." Fact Sheet. Washington DC: White House, 13 May 2003. <http://www.au.af.mil/au/awc/awcgate/space/2003remotesensing.htm> [3 December 2003].

Rees, Gareth. The Remote Sensing Data Book. Cambridge, UK: Cambridge University Press, 1999.

Russo, Anthony J. "The Operational Denial of Commercial Space Imagery." Unpublished Research Paper, U.S. Army Command and General Staff College, Ft Leavenworth, KS: 1996.

Satellite Imaging Corporation Website. <http://www.satimagingcorp.com/> [12 January 2004].

Shumate, James R. "Information Weaponization of Space." Unpublished Research Paper, U.S. Naval War College, Newport, RI: 2001.

Smith, Marcia S. "U.S. Space Programs: Civilian, Military, and Commercial." CRS Issue Brief for Congress, Washington DC: Congressional Research Service, Updated October 6, 2003.

Sowa, Michael J. "Shutter Control Feasibility and Employment Considerations." Unpublished Research Paper, USAF Weapons School, Nellis Air Force Base, NV: 2000.

Space Imaging, Inc. Website. <http://www.spaceimaging.com/> [25 January 2004].

Tag's Broadcasting Services Website. "The Satellite Encyclopedia." <http://www.tbs-satellite.com/tse/online/mis_teledetection_res.html> [12 January 2004].

"Taiwan's Use of Satellites for Surveillance Against China Described." FBIS. Translated from Guangzhou Guangzhou Ribao (Internet Version), 16 February 2003. <http://www.fbis.cia.sgov.gov/doc_lib/2003/002/10/CPP20030219000068N.html> [9 January 2004].

Topographic Engineering Center Imagery Office Website. <http://www.tec.army.mil/tio/index.html> [30 January 2004].

U.S. Department of Defense. "Defense Strategy." Quadrennial Defense Review. Washington DC: May 1997. Referenced in Frank G. Klotz, "Space, Commerce, and National Security." A Council of Foreign Relations Paper. New York: Council of Foreign Relations Press, 1998.

U.S. Joint Chiefs of Staff. Department of Defense Dictionary of Military and Associated Terms. Joint Pub 1-02. Washington DC: 12 April 2001 (As Amended Through 5 June 2003).

____. Joint Doctrine for Space Operations. Joint Pub 3-14. Washington DC: 9 August 2002.

____. Joint Vision 2020. Washington DC: June 2000.

____. Joint Warfare of the Armed Forces of the United States. Joint Pub 1. Washington DC: 14 November 2000.

Zeigler, David W. "Safe Heavens: Military Strategy and Space Sanctuary." In Beyond the Paths of Heaven: The Emergence of Space Power Thought, edited by Bruce M. DeBlois, 185-245. Maxwell Air Force Base, AL: Air University Press, 1999.